Optimizing Facility Component Maintenance, Repair, and Restoration Investment Strategies Using Financial ROI Metrics and Consequence Analysis

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Abstract

In order to proactively manage facility assets and allocate resources to optimize facility performance, infrastructure asset management professionals at all levels need improved decision support tools and processes. This paper addresses the business process framework for developing a comprehensive facility infrastructure investment plan using information about current and projected future asset condition. This process starts by identifying which building components are candidates for corrective repair or replacement using standards and policies linked to acceptable building performance requirements. Next, a prioritization schema determines which work actions are most important for funding when budgets are constrained. Priorities are developed through importance and condition metrics, risk assessment, penalty costs of not doing work, and return on investment (ROI) analysis and metrics. These financial metrics also help to determine the best option between component stop-gap repair, major repair, or total replacement alternatives by evaluating the economic return over the lifecycle of the asset. Finally, consequence analysis simulations determine the impact of difference standards, policies, and budget levels, further maximizing building performance and return on investment.

Introduction

Decision support technology for planning building facility maintenance, repair, and capital renewal has evolved over the past several decades from a reactive breakdown mode to a predictive, reliability centered approach (Moubray 2002). This evolution has been predicated on improved assessment techniques and metrics, which provides the basis for better decision support and justification for work requirements. However, a full and detailed building assessment program and work requirements formulation can be prohibitively expensive for many organizations, and they revert back to the short term costs savings (through reduced inspections) associated with reactive maintenance and repair. In the long term, this decision eventually leads to chaotic fiscal swings and inopportune downtimes for many maintenance organizations. So as the shifting focus towards proactive asset management calls for accurate accounting and assessment of building infrastructure, it also requires an improved knowledge-based process to balance repair and inspection resource planning based on acceptable risk and asset criticality. This involves just-in-time assessments and timely corrective action before advancing degradation leads to more costly repairs or impact on organizational goals and mission. Next-generation processes for condition assessment, condition prediction, work requirements generation, prioritization, and consequence analysis are all important features of this changing asset management environment.

State of the Practice in Building Facility Asset Management

The merit of proactive maintenance and inspection of buildings is not a new concept. Past and current practices employ trained engineers or specialty technicians to inspect and evaluate various aspects of a building. These inspections are designed primarily to 1) ensure the safety of the building for the occupants; 2) determine maintenance, repair, or modernization requirements. With each assessment, the inspector surveys the building and records deficiencies, which relate to corrective service calls or repair and restoration work. The inspector may also assign a priority code which reflects the importance or urgency of the deficiency. This puts the work prioritization process in the hands of several different inspectors, instead of under centralized, consistent, information driven process.

After the inspection identifies building deficiencies that need to be addressed, a project engineer or technician often will draw up a detailed plan for correcting the deficiencies, develop a bill of materials, and a cost estimator will determine the project costs. This labor intensive and expensive process results in a "job jar" of projects based on the often subjective input from many different inspectors. In addition, if the total work requirement exceeds the budgeted amount, (as is most often the case) wasted design and estimating effort results from unfunded projects that never get completed. Therefore, inspection programs can become questionable in value and many programs end up abandoned due to lack of funding or justification to support them.

Performance-Based Metrics

To improve on this process described above, facility performance metrics are needed which are 1) affordable to obtain within the organizational framework; 2) Consistent, objective, and repeatable across different inspectors and assessors; 3) engineering and science-based; and 4) correlated to physical condition, work requirements, and resource justification. One single metric does not address all these requirements. Instead, a collection of engineering and economic derived metrics provides a toolkit for facility managers to base investment decisions. These metrics include:

- A Condition Index (CI) metric that provides an objective measure of the physical condition of an asset on a 0-100 point scale from a standardized distress-based, not deficiency-based, inspection process (Uzarski and Burley 1997),
- A Functionality Index (FI) metric that provides an objective measure of built-in capability of an asset or facility to perform its required function based on defined organizational mission or goals, obsolescence, and codes/regulations. The functionality metric is measured on a similar 0-100 point scale based from a standardized functionality evaluation,
- A Performance Index (PI) metric that is a function of condition and functionality, and relates how well a building performs as required by mission as the building ages, degrades, and obsolesces,
- A Remaining Service Life (RSL) metric that relates the expected remaining amount of time a building component asset will perform at or above a required minimum level of performance,
- A Remaining Maintenance Life (RML) metric that relates the expected remaining amount of time a building component will perform above a desired condition standard,
- A Component Importance Index (CII) that measures the criticality of a component asset against risk of failure, and
- A Mission Dependency Index (MDI) that measures the importance of a building with respect to agency or organizational mission. (Mission Dependency Index)

These metrics describe the state of the building or component asset at a measured point in time based from assessment information. In addition, the Condition Index metric provides a means for predicting future asset condition and reliability using trend analysis. This allows for the development of long term work plan strategies and consequence analysis. The CI is the main metric discussed within the scope of this paper.

Determining Candidates for Corrective Action

The Condition Index describes the absolute condition of an asset on 0-100 scale (Table 1). It also establishes a means to compare all building component conditions on a relative scale. A condition standard specifies a threshold CI value for an asset or group of assets to establish a target condition below which the assets become candidates for corrective action. Not all components in a building are required to be maintained at the same standard level. Therefore, multiple condition standards may exist and a policy based on organizational goals and accepted risks will identify which components should be maintained at a high condition and which can be maintained at lower condition levels. These standards can be selectively applied based upon several attributes of the components, such as the type of building or building system the component resides in, and the effect of component failure on mission.

Table 1. Condition Index Definitions

Condition Index	Definition
100-85 Good	Slight or no serviceability or reliability reduction overall to component.
85-70 Satisfactory	Component serviceability or reliability is degraded but adequate.
70-55 Fair	Component serviceability or reliability is noticeably degraded
55-40 Poor	Component has significant serviceability or reliability loss.
40-25 Very Poor	Unsatisfactory serviceability or reliability reduction
25-10 Serious	Extreme serviceability or reliability reduction
10-0 Failed	Overall degradation is total.

Evaluation of Corrective Work Action Scenarios using ROI

The cost to accomplish the work can be estimated from a model. Each building component has an associated replacement value. When component repair is warranted, the estimated corrected work action cost is some percentage of total replacement cost. As illustrated in Figure 1 below this percentage is a function of CI. It also varies by component. Due to the curvilinear nature of the repair $ versus CI curve, deferring repair opportunities early in a component lifecycle can have a significant impact later on repair costs, making repair a less viable option than total replacement.

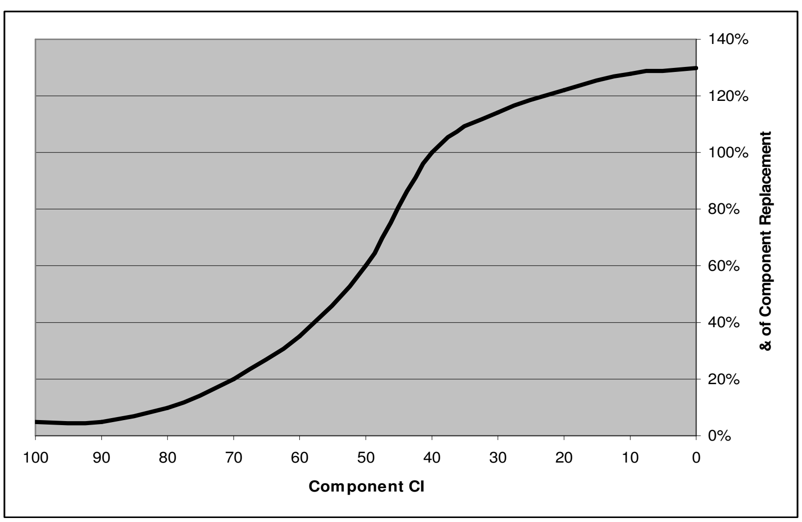

Figure 1. Component Repair Cost as a Function of CI.

The key to minimizing the total component lifecycle cost is by maximizing the benefit or return on any repair or capital investments over the lifecycle. Figure 2 shows the typical condition profile of a component over its expected service life, with the lifecycle response due to several corrective action alternatives. As the component operates in service and ages, its condition degrades, usually after several years of relatively high steady-state condition. When this degradation reaches the threshold limit set by the standard, corrective action alternatives are explored. These corrective actions include: 1) do nothing – allow the component to run until failure; 2) Stop-Gap repair; 3) major component repair; and 4) total component replacement.

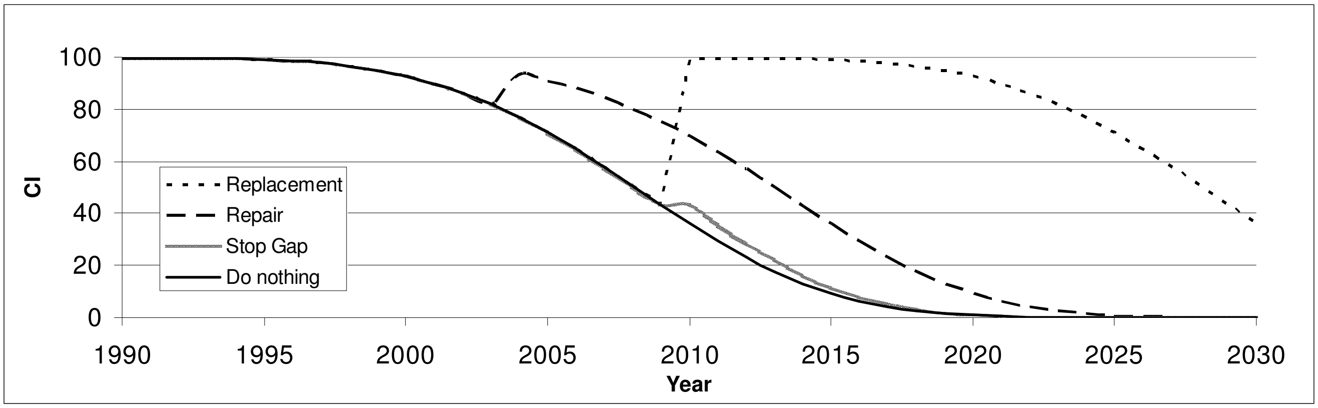

Figure 2. Component Lifecycle Trends for Corrective Action Alternatives

Run to Failure

If no corrective action is performed on the component, its condition, performance, and eventual reliability will degrade to such a point, termed the CI terminal value, where failure has essentially occurred. At this point, component replacement is required. The run to failure option is viable only if component failure does not have a significant impact on mission.

Stop Gap Repair

For some components where advancing degradation is evident, measures can be taken to slow or halt this degradation for some finite amount of time. These measures are limited in scope and do not improve or restore condition, but they can prevent the component from degrading below some minimum performance requirement until a more permanent solution can be accomplished. Stop gap repairs are usually less attractive from an economic perspective, because they do not improve condition and only defer larger major repairs or replacement for a short amount of time, but may be needed due to a lack of funds for a permanent solution.

Major corrective Repair

Major repair improves the condition of the component (not necessarily to 100) sometime prior to failure. Due to this increase in condition, the component's remaining service life is also extended. This additional service life, brought on by repair, defers the capital cost of replacement due from impending failure. Therefore, the monetary benefit of a repair can be calculated by taking the additional service life generated by the repair multiplied by the amortized expenditure of component replacement. This monetary benefit, divided by the cost of the repair, determined the return on the investment (ROI) (ASTM E833-02a). The repair of a component also has benefits due to improved operational performance and reliability which are more difficult to quantify in monetary terms.

Replacement/Capital Renewal

Complete component replacement essentially resets the component lifecycle clock. When replacement is performed, the component CI is restored to its maximum (CI=100) and the full expected service life is reset. Since replacement does not defer capital expense, its return of investment ratio based on the logic described for repair is essentially 1. However, replacement of a component may involve some modernization, potentially resolving obsolescence issues. This, in turn, can lead to benefits of efficiency and lower maintenance, operations, or energy costs, which should be accounted for in any ROI calculation (ASTM E1074-93).

The procedures discussed above provide a logical framework for calculating an ROI for different corrective action alternatives. The analysis can also be used to determine the best time for scheduling and executing component repair or replacement. The extended service life gained from a corrective repair action, and the cost of the repair both depend on when that action takes place, and the condition of the asset at the time. Hence, there is an optimal point for each building component for corrective work to occur. The ROI analysis procedures can be used to pinpoint optimal work timing and establish the remaining time in service before maintenance is warranted.

Prioritizing Work

Typically, the total estimated costs for all corrective work item candidates will exceed the authorized budget. Hence, a ranked work item list is necessary. This ranking should reflect the importance of both the building and component and the potential ROI for doing work at the specified time plus other variables. In so doing, an objective prioritization scheme must be based on the priorities of the organization and the risk associated with investment alternatives.

The development of a prioritization scheme starts with the definition of organizational objectives and the evaluation of how well a given component or its work action meets those objectives. This is done by specifying attributes of the building, component and work item which can be related to importance measures. For example, one objective is accomplishing the most cost efficient work items. In this case, the main prioritization criterion is the calculated ROI metric. Another, sometimes competing objective, is repairing the most important component based on mission criticality. Here, the different measures associated with building use type, building systems, and the MDI and CII metrics are prioritization criteria. By assigning relative weights to the different measures and objectives, a consistent and repeatable importance score is calculated for each work item, which is then used to rank work items and establish the funding cut line based on the budget.

Consequence Analysis

A long term maintenance, repair, and capital renewal plan for an organization can involve a portfolio of several buildings with hundreds of building components in each, all at varying condition states. This plan may seek to identify work requirements over a five to ten year horizon. With the numerous asset elements involved, optimizing a strategy that incorporates current user requirements, budget constraints, and future performance sustainment can be a difficult challenge. Using a structured business process framework, and component degradation analysis, different investment decision scenarios can be explored, and consequences can be evaluated over a long-term horizon.

One such automated consequence analysis tool is the IMPACT simulation model (IMPACT) used in conjunction with the BUILDER® Engineered Management System (BUILDER). This model simulates the annual fiscal cycle of work planning/executing and displays building, system, and component conditions up to ten years into the future. Model inputs include the real property inventory, condition information and deterioration trends, current work projects, budget projections, and user defined standards, policies, and prioritization schemes to initialize the model. The simulation then 1) generates work requirements based from projected conditions, user defined standards and policies 2) prioritizes work actions 3) assigns funding to highest priority work items using set budget resources 4) simulates the execution and completion of funded work 5) predicts the future condition of component assets based on work completed and deferred and 6) updates the component inventory database to reset the cycle for each year in the simulated budget plan.

After simulation, a complete picture of the condition response of the portfolio of assets is known for the duration of the scenario horizon (Figure 3). In addition, the maintenance and repair (M&R) backlog due to deferred work requirements is available for each year in the plan (Figure 4). This gives facility managers and decision makers the ability to see the effects of budget and policy on the condition of facility assets over time, and adjustments can be made accordingly to maximize performance and return on investment.

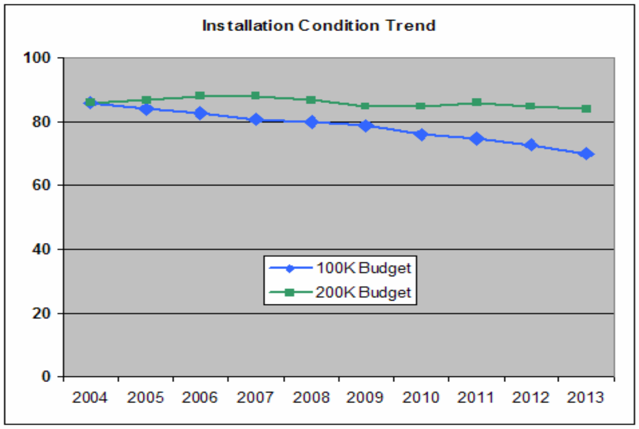

Figure 3. IMPACT Scenario Condition Trend

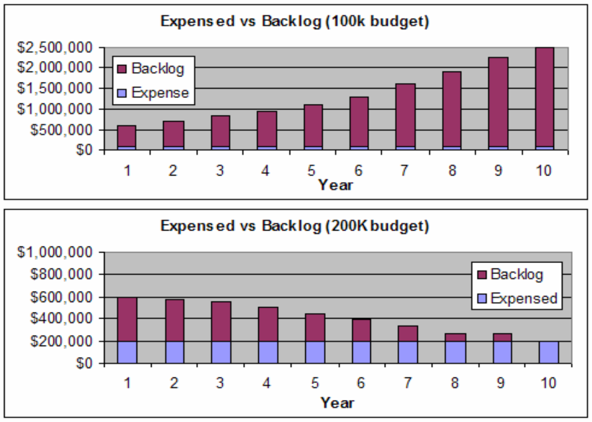

Figure 4. IMPACT Scenario M&R Backlog

Conclusions

Fundamental to any successful facility infrastructure investment strategy are the objectives to 1) minimize lifecycle ownership costs, 2) maximize facility performance, and 3) manage risk. The process described herein provides the framework and decision support to help facility managers achieve these objectives. A distress-based condition assessment process is standardized, affordable, and results in a Condition Index metric that provides performance-based information about condition state, condition prediction trends, and remaining service life that are objective, consistent, and meaningful across all building components and infrastructure domains. The CI establishes the foundation for risk-based condition standards, component reliability projections, and best cost work planning and timing, and presents a rational and streamlined approach to work generation, work estimation, financial analysis computation, and prioritization. Finally, the consequence analysis routines provide the critical ability to evaluate the effect of infrastructure investment policies against the fundamental strategic objectives. This supports proactive and accountable building infrastructure management. By implementing this approach, such as through the BUILDER® EMS, a scalable, enterprise-wide solution can support work planning activities, and achieve organizational organization or agency-level mission, goals, and performance benchmarks for facilities.

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